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BEST AVAILABLE SCIENCE ISSUE PAPER: WATERCOURSES

Prepared for:

City of Tukwila
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1.0 INTRODUCTION

1.1 Project Authorization

At the request of the City of Tukwila, Adolfson Associates, Inc. (Adolfson) has prepared this issue paper to provide an overview of the "best available science" pertaining to management of streams found in the City of Tukwila (the City). The preparation of this report was made possible by funds made available through the Washington State Department of Community, Trade and Economic Development. This paper will provide guidance to the City in development and revision of the City's critical areas ordinance – Tukwila Municipal Code (TMC) Chapter 18.45 Sensitive Areas Overlay.

This paper discusses the results of the best available science review for streams and evaluates the applicability of the science to stream regulations in the City. Adolfson has based our review of the city environment on two days of field investigation, existing literature and preliminary information from the City regarding its update of the stream inventory. City staff are in the process of updating the watercourse inventory, and this preliminary review of Best Available Science will be updated with inventory information and GIS products at a later date. A review of the best available science in relation to shorelines in the City of Tukwila was prepared by others but available for review (Pentec, 2002).

1.2 Overview of Growth Management Act Requirements

In 1995, Washington State's legislature added a new section to the state's Growth Management Act (GMA) to ensure that cities and counties consider reliable scientific information when adopting policies and regulations to designate and manage critical areas. The new section, RCW 36.70A.172, requires all cities and counties to include "best available science" in developing policies and regulations to protect the functions and values of critical areas. One of the objectives of GMA is to protect the functions and values of critical areas by (1) accurately describing these functions and values; (2) understanding the likely adverse impacts associated with proposed land use planning alternatives; and (3) making land use decisions that minimized or eliminated those adverse impacts to the extent possible.

The state's Office of Community Development (OCD) adopted procedural criteria in 2002, to implement these changes to the GMA and to provide guidance for identifying best available science. The rule makers concluded that identifying and describing functions and values and estimating the types and likely magnitudes of adverse impacts were scientific activities. Thus, RCW 36.70A.172(1) and implementing regulations require the substantive inclusion of best available science in developing critical area policies and regulations. These policies and regulations must also give "special consideration" to preserve or enhance anadromous fisheries, including salmon. Subsequently, local government adopting policies and development regulations to protect critical areas needs to document that it has given special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries. Local governments should document that these measures are grounded in the best available science. The rule states that special consideration should be given to habitat protection measures based on the best available science.

The purpose of this report is to summarize and discuss the best available science relating to the functions and values of streams and riparian areas, particularly relating to the needs of anadromous fisheries in the City of Tukwila (City). This report is intended to accompany the stream inventory currently being prepared by City staff (in progress).

1.3 Overview of the City Environment

The City of Tukwila is an incorporated city with a population of approximately 15,000 located in King County, Washington. Tukwila and its planned annexation areas occupy approximately 10 square miles, and are generally bounded by the cities of Seattle to the north, Renton to the east, Kent to the south, and SeaTac to the southwest.

The Green/Duwamish River is the main water feature in the City, flowing south to north through the planning area. Along with the river, there are seven major tributaries and several minor ones that drain into the Green/Duwamish River within Tukwila. A detailed stream inventory is being prepared by the City. In the Tukwila Municipal Code (TMC), tributary streams are called watercourses, which are defined in TMC 18.06.920 as:

> "...a course or route formed by nature or modified by man, generally consisting of a channel with a bed and banks or sides substantially throughout its length along which surface water flows naturally other than the Green/Duwamish River. The channel or bed need not contain water year-round. Watercourses do not include irrigation ditches, stormwater runoff channels or devices, or other entirely artificial watercourses unless that are used by salmonids or to convey or pass through stream flows naturally occurring prior to construction of such devices."

Tukwila is a largely urbanized city, and a substantial portion of the development that has occurred in the City has been commercial and industrial in nature. The most heavily industrial areas are located along the Green/Duwamish River, and water-based commerce has been, and continues to be, an important component of these commercial and industrial activities. Development of the immediate shoreline of the Green/Duwamish River is constrained by a series of levees. In general, most easily-developable areas within the City limits have been developed. Some redevelopment is occurring, as is development on some hillsides.

2.0 STATE OF THE SCIENCE FOR WATERCOURSES AND RIPARIAN AREAS

This section summarizes the state of the science, or "best available science" for streams and stream buffers. Higher preference has been given to science and research conducted in the Pacific Northwest versus research from other areas of the United States. This information is a summary of existing literature and is not intended to be an exclusive list of all best available science currently published on streams, but is intended to provide a brief overview of scientifically valid information useful for local planning and regulatory review. Adolfson has referenced findings from selected scientific literature where applicable, including relevant studies from the Office of Community Development's "Citations of Recommended Sources for Designating and Protecting Critical Areas."

2.1 Importance of Watercourses and Riparian Areas

Stream systems are one of the most productive natural systems. Riparian areas play a significant role in the protection of the functions of adjacent aquatic habitats. Both provide important habitats for aquatic species and other wildlife as well as contribute to recreation, water supply, economic, cultural and historic values. Specific watercourse functions are discussed in the following section.

2.2 Functions and Values of Watercourses

Elements necessary for healthy salmonid populations and for other aquatic organisms rely on processes sustained by the dynamic interaction between the stream and the adjacent riparian area (Naiman et al., 1992).

- Maintaining stream baseflows;
- Maintaining water quality;
- Providing in-stream structural diversity; and
- Providing biotic input of insects and organic matter.

2.2.1 Stream Flow

Stream flow is the amount and velocity of water flowing in a stream. In urban systems, discharge regimes are often substantially altered. Urbanization changes the volume, rate, and timing of water flowing through stream systems, which can impact the physical characteristics of the stream channel (Booth, 1991). Stream degradation has been associated with the quantity of impervious surface in a basin (Booth, 2000; May et al., 1997; Horner and May, 2000). Studies in Puget Sound lowland streams show that alteration can occur in basins with as little as 10 percent total impervious surface. However, dramatic effects can be seen relative to discharge in basins where impervious surface exceeds 40 percent (May et al., 1997). In addition, medium-sized flood events in moderately urbanized watersheds are found to have peak-flow increases of two to three times the amount of runoff than non-urbanized watersheds (Booth et al., 2000). Increases in peak flow are more apparent as smaller, more frequent floods relative to larger floods (Booth et al., 2001).

Stream flow or discharge has a significant influence on salmonids during their various life stages. The quantity of stream water available for use by fish and other aquatic species will determine how habitats will be effectively used in a particular basin. Adult chinook and steelhead, for example, require greater water depths to spawn as compared to other salmonids, and thus, commonly spawn in larger streams. Smaller species, such as cutthroat trout and coho salmon, can successfully spawn in smaller headwater streams (Wydoski and Whitney, 1979). Reaches of streams that are dry or have low flows in summer may limit summer rearing habitat for these species. While low flows may limit access to some streams or reaches, excessively high flows can also affect both stream habitat and reproductive success. Riparian areas often have shallow groundwater tables, as well as areas where groundwater and surface waters interact. Groundwater flows out of riparian wetlands, seeps, and springs to support stream baseflows. Surface water that flows into riparian areas during floods or as direct precipitation can infiltrate into groundwater in riparian areas and be stored for later discharge to the stream (Ecology, 2001; City of Portland, 2001). Stream baseflow is particularly important to stream-flow sensitive salmonids in the Pacific Northwest, because riparian areas provide baseflow from groundwater during the region's typically dry season (City of Portland, 2001; Booth, 2000; May et al., 1997; Schueler, 2001).

2.2.2 Water Quality

Salmonid fish requires water that is both colder and has lower nutrient levels than many other types of fish. High water quality is a crucial need of all native salmonid fish and is important to other aquatic species adapted to living in Pacific Northwest streams as well. Parameters for salmonids in particular are discussed below.

2.2.2.1 Water Temperature

While no single temperature provides for all of the needs of all species or life stages of salmonid fish, many authors have identified water temperature ranges suitable for the various species and developmental stages of salmonids (EPA, 2001; City of Portland, 2001; Sullivan et al., 1990). The general range of temperatures required to support healthy salmonid populations is generally considered to be between about 39° and 63° F (NMFS, 1996; USFWS, 1998). Cutthroat trout have the highest range of temperature tolerances of native salmonids (Pauley et al., 1989 in City of Portland, 2001). Above 63° F, however, salmonids begin to exhibit stress that may cause sublethal effects including reduced growth and overall survival. Stresses increase until temperatures exceed lethal limits (Moyle and Cech, 1998; Thomas et al., 1986). Lethal limits vary widely by species and development stage; constant temperatures in excess of 78° F, as one example, are within the lethal range for coho salmon (Thomas et al., 1986). Coho salmon are less tolerant of high stream temperatures than other salmonids because they usually spend a full year in freshwater. Riparian vegetation, particularly forested riparian areas, can affect water temperature by providing shade to reduce solar exposure and regulate high ambient air temperatures, ameliorating water temperature increases (Brazier and Brown, 1973; Corbett and Lynch, 1985).

2.2.2.2 Dissolved Oxygen

Dissolved oxygen is one of the most influential water quality parameters for stream biota, including salmonid fish (Lamb, 1985). The most significant factor affecting dissolved oxygen levels in most streams is temperature, with cooler waters maintaining higher levels of oxygen than warmer waters (Lamb, 1985). Other factors that can contribute to oxygen levels includes water turbulence (the amount of aeration) and biochemical oxygen demand created by organic decomposition from natural organic materials, organic pollution (pet waste, sewage, etc.), and aquatic algae respiration. Nutrients may originate from human-induced sources such as fertilizers (both chemical and natural), pet waste, and leaking sewers, or from natural processes such as decomposing algae or dead plant materials that fall into streams (Lamb, 1985).

2.2.2.3 Metals and Pollutants

Common pollutants in urban areas include nutrients such as phosphorus and nitrogen, pesticides, bacteria, and miscellaneous contaminants such as PCBs and heavy metals. Impervious surfaces collect and concentrate pollutants from different sources and deliver these materials to streams during rain storms. In general, concentrations of pollutants increase in direct proportion to total impervious area (May, et al., 1997). Undisturbed riparian areas can retain sediments, nutrients, pesticides, pathogens, and other pollutants that may be present in runoff, protecting water quality in streams (Ecology, 2001; City of Portland 2001).

Elevated nitrogen and phosphorus levels in runoff are a typical problem in urban watersheds. They can lead to increased in-stream plant growth, which results in excess decaying plant material that consumes oxygen in streams and reduces aquatic habitat quality (Kerwin, 2001). Metals and hydrocarbons are often transported with sediments. Heavy metals, Polychlorinated Biphenyls (PCBs), and other contaminants may be toxic to fish and wildlife (Kerwin, 2001). The primary sources of metals and hydrocarbons in urban areas appear to be industry and automobiles (Lynch et al., 1985). Gas and oil, toxins from rooftops, and industrial and household chemicals (paint, cleaning products, etc.) are also pollution sources in streams.

The extent to which salmonids are exposed to toxic substances such as pesticides is largely unknown (Washington Department of Agriculture et al., 2001). Toxic substances can have an acute and/or chronic effect on salmonids and other aquatic organisms, and the toxicity of many elements depends on independent factors (Kerwin, 2001). The acute effects of toxic discharges are easy to observe as they are often the result of an episodic event where large numbers of fish are killed. However, chronic impacts such as effects on growth or reproduction, occur over time and may not be readily connected to a single source or event.

2.2.3 In-stream Structural Diversity

Salmonid species utilize a wide variety of both fresh and saltwater habitats. However, there are several general habitat elements that support many species of salmonid fish. The National Marine Fisheries Service (NMFS, 1996) and U.S. Fish and Wildlife Service (USFWS, 1998) have developed guidelines to address habitat physical elements necessary to support healthy salmonid populations across this range of variability. These physical habitat elements are discussed below.

2.2.3.1 Substrate

Under natural conditions, the redistribution of substrate through bank erosion and channel movement is a natural occurrence and is necessary to maintain clean, sediment-free gravels. In urban basins, increases in stormflow quantities and velocities can cause scouring that can displace stream substrates, which in turn reduces the quality and quantity of spawning areas

(May et al., 1997). Scouring can result from increased runoff from impervious surfaces and from increases in velocities as a result of channelization (straightening) and the removal of streamside vegetation. Increased runoff rates from impervious surfaces can also flush spawning gravel from streams (Bledsoe and Watson, 2001).

To balance the displacement of gravel resulting from natural redistribution or scour, streams must have a constant source of new material. However, when vegetated riparian corridors have been developed with urban land uses and stream banks stabilized to protect development, there is little gravel or woody debris that it allowed to move to the stream system (May et al., 1997). In general, armoring of stream banks with riprap or revetments reduces the supply of gravel and LWD (May et al., 1997).

A wide variety of substrate sizes within a stream may provide habitat for use by several different salmonid species. Fine sediments such as sand and silts can fill spaces between gravel and reduces the opportunities for spawning and reproduction (Murphy et al., 1981; Thornon et al., 1997).

2.2.3.2 Large Woody Debris

Large woody debris serves many functions in the stream environment, which creates habitat diversity (for example pool habitat for rearing and cover for refuge). Woody debris adds roughness to the stream channel, which slows water velocities and traps sediment (Shirvell, 1990). Because coniferous logs are slower to decompose, they generally provide more benefit as large woody debris than deciduous species (May et al., 1997).

Sources of large woody debris are often limited in urban stream systems. Movement of the stream channel, undercutting of banks, windthrow, and flood events are all methods of recruitment of woody debris to the stream. However, when riparian areas have been cleared and developed, and the stream bank stabilized for development, there is little large woody debris available for recruitment (May et al., 1997). This is frequently the situation in urban streams where large conifers have been removed, during land clearing and development activities in or adjacent to riparian corridors, or where large woody debris may be removed from streams to reduce perceived hazards associated with flooding. Man-made features such as culverts or bridges, which restrict the ability of the stream to pass woody debris downstream, also hinder recruitment. Increased runoff rates from impervious surfaces can also flush large woody debris from streams (Bledsoe and Watson, 2001).

Many authors have found that more than half of all large woody debris recruitment is from within 15 feet of streams, and about 90 percent comes from trees growing within about 50 feet of streams (Murphy and Koski, 1989; McDade et al., 1990; Van Sickle and Gregory, 1990).

2.2.3.3 Pool Quality and Quantity

Large, deep pools with cover provided by woody debris, overhanging vegetation, or other features such as boulders, typically provide more habitat value than smaller, shallow pools (May et al., 1997). Adult salmonids of all species require pools with sufficient depth and cover to protect them from predators during their spawning migration. Adult salmon often hold in pools during daylight, moving upstream from pool to pool at night.

Pools, although important for most species of salmonid fish, are just one type of habitat that salmonid fish require. Multiple habitats allow niche separation to occur so multiple populations of fish with similar habitat needs can be maintained. Other habitats, like riffles and glides, are also needed to provide the full complement of habitats necessary to support the range of salmonid species and development stages present. Riffles provide habitat for many of the aquatic insects that rearing salmonids utilize as food. Riffles and cascades create turbulence that contributes to increase stream dissolved oxygen levels. Some salmonids may prefer pools, but can also successfully compete using other habitat types. Cutthroat trout are often found in faster water habitats such as glides and riffles. One study of urbanizing basins found that, for multiple reasons including competition, physiology, and food preferences, cutthroat trout densities may actually increase in streams that have lower pool frequencies compared to more diverse pristine systems (May et al., 1997).

2.2.3.4 Floodplain Connectivity and Off-Channel Refugia

Off-channel wetlands and side channels in riparian areas provide foraging habitat, over-wintering habitat, and refuges for rearing fish (Swales and Levings, 1989; City of Portland, 2001). These areas, which includes wetlands connected to the stream channel and side channel habitats, also have high levels of productivity and provides areas for juvenile fish to forage and grow before outmigrating to salt water. Previous studies have shown the importance of off channel and river margin rearing habitat to juvenile chinook (Bjornn and Reiser, 1991). Juvenile coho salmon, which are not strong swimmers compared to other juvenile salmonids, often spend the winter rearing in quieter off-channel pools and wetlands with ample woody debris cover (Bisson, et al., 1988). Studies in urban and urbanizing areas indicates that off-channel habitat and refugia may be reduced by urban development (Kerwin, 2001). Causes of this loss includes channel straightening and disconnection from adjacent wetland areas.

2.2.4 Biotic Input

Riparian areas provide food for salmonids, both directly and indirectly (Meehan et al., 1977). Insects falling from overhanging vegetation provide food for fish, while leaves and other organic matter falling into streams provide food and nutrients for many species of aquatic insects, which in turn provide forage for fish. In Puget Sound lowland streams, leaf litter from adjacent forested riparian areas is a primary source of organic carbon and nutrients (Horner and May, 1999). Many species of aquatic invertebrates have become adapted to feed on dead and decomposing organic material that has fallen or washed into the stream from adjacent uplands (Benfield and Webster, 1985).

Salmonids consume a wide range of food sources throughout their life cycles. Most juvenile salmonids that rear in streams prey on aquatic invertebrates and terrestrial insects that fall into streams from overhanging vegetation (Horner and May, 1999; May et al., 1997). In some streams during the summer, an estimated 50 percent of the diet of juvenile salmonids is comprised of terrestrial insects (City of Portland, 2001). Availability of stream invertebrates as a prey source for salmonids depends on both habitat area and habitat quality; specifically, the amount of stream that can produce prey organisms and the amount of habitat that provides opportunity for fish to exploit the prey base.

3.0 FUNCTION AND VALUES OF RIPARIAN BUFFERS

Riparian buffers along stream banks help mitigate the impacts of urbanization and disturbance on adjacent lands (Finkenbine et al., 2000 in Bolton and Shellberg, 2001). Knutson and Naef (1997) summarize many of the functions of riparian buffers for Washington. The Washington Department of Fish and Wildlife's (WDFW) recommended standard buffer widths for the state's five-tier stream typing system is based on this latter research (Table 1) (OCD, 2002).

Table 1. Riparian Habitat Area Buffer Recommendations: Washington Department of Fish and Wildlife

Stream Type	Recommended Riparian Width
Type 1 & 2, shorelines of statewide significance	250 feet
Type 3 or other perennial or fish bearing streams, 5-20 feet wide	200 feet
Type 3 or other perennial or fish bearing streams, less than 5 feet wide	150 feet
Type 4 and 5 (low mass wasting potential)	150 feet
Type 4 and 5 (high mass wasting potential)	225 feet

Source: OCD, 2002; For definitions of the stream types see the Washington Administrative Code Sections 222-16-030 and 031.

Buffer widths reported to be effective for riparian functions vary considerably; the literature is not definitive in identifying one buffer width for each function studied (Williams and Lavey, 1986; Johnson and Ryba, 1992). The wide range of reported effective buffer widths indicates that site-specific factors are important in determining the outcome of each study. Buffer studies have been conducted in a wide variety of locations (e.g., Puget Sound lowlands, montane forests of the Cascade Crest), and land use settings (primarily agricultural and forestry) using a variety of research methods. Moreover, studies have been conducted in a wide range of channel types (e.g., stream order, channel size, channel morphology) and site characteristics (e.g., slope, aspect, soil type, vegetative cover). Most of the available research has been conducted in forestry settings where the focus has been to document the effects of timber harvest.

A general relationship between buffer width and buffer effectiveness is apparent in the research findings (Appendix A). Studies indicate that buffers 100-to 150-feet (30 to 45 meters) wide provide most (on the order of 80 percent) of the potential functions. The literature also indicates that the relationship between buffer width and effectiveness is logarithmic, so that after a certain width an incremental increase in buffer width provides diminishing functional returns. However, there is little research on effectiveness of riparian buffers in urban environments (Herson-Jones et al., 1995). Buffer distances should be viewed mainly as guidelines, as the literature shows that site-specific factors may impact buffer effectiveness just as much as buffer width (Naiman et al., 1992; Castelle et al., 1994).

3.1 Application of Buffer Widths

The geomorphic settings of streams influence their fluvial characteristics, which in turn influence their channel migration zone, ability to absorb flood flows, and the ability buffers to provide their various functions. An overall conclusion of the review of scientific literature is that buffer widths required to protect a given habitat function or group of functions depends on numerous site-specific factors. The importance of riparian functions can vary by stream size and channel width. Small headwater tributary streams are strongly influenced by riparian vegetation, where such vegetation provides shading of waters and contributes large amounts of organic material. Temperatures in larger streams below headwaters benefit less from overhanging vegetation. Diversity of a plant community (species, density, age) in a buffer may determine how well a buffer will perform functions. Aspect, soil type and slope all play a role in buffer effectiveness. In riparian areas located on steep slopes and/or highly erodible soils, larger buffers may be appropriate to reduce risks of erosion and delivery of fine sediment to streams. In general, as stream size increases, the importance of shading and terrestrial organic inputs decrease, with a increasing significance of algal or rooted vascular plant production and organic transport from upstream (Vannote, et al., 1980).

Studies of buffer widths for moderation of stream temperatures generally range from 35 to 150 feet (Appendix A; Knutson and Naef, 1997). Much of the variability in the literature is related to the presence or absence of a mature tree canopy. For example, forested buffers of 75 to 100 feet were found to provide 60 to 80 percent of the shade of conditions in fully forested watersheds (Brazier & Brown, 1973; Steinblums et al., 1984).

Recommended buffer widths for sediment and pollutant retention vary from 15 to 860 feet (Appendix A; URS, 2002; Knutson and Naef, 1997). This wide variation is due in general to the particular pollutant being evaluated. Buffers of 50 to 100 feet may provide substantial pollutant removal benefits, and can remove 75 to 80 percent of pollutants depending on site-specific conditions and buffer type (Lynch et al., 1985; Castelle & Johnson, 2000; Wong & McCuen, 1982; Castelle et al., 1992). Studies have concluded that buffers of 100 feet can achieve sediment removal efficiencies of 75 to 100 percent. Wong and McCuen (1982) indicate that 90 percent of sediment removal can be accomplished within the first 100 feet of a riparian buffer, but an additional 80 feet of buffer is required to remove five percent more sediment (Appendix A). Most papers also conclude that larger buffers are required on steeper slopes to reach the same level of pollutant removal.

Riparian vegetation may contribute up to 90 percent of the biotic input in stream systems (Budd et al., 1987). Recommended buffers for maintenance of benthic communities range from 33 feet to greater than 100 feet. However, most studies found that buffers of 100 feet were necessary maintain healthy benthic communities (Roby et al., 1977; Newbold et al., 1980; Castelle & Johnson, 2000). Buffers exceeding 100 feet were found to maintain the benthic diversity of unlogged forested basins (Erman et al., 1977; May et al., 1997). Although vegetated buffers are necessary for organic input, no studies have focused on effective buffer widths specifically for biotic input functions.

Because riparian areas store and slowly release water, they provide a continuous flow of water to streams. A standardization of buffer width for stream baseflow has not been studied thoroughly.

The effectiveness of the buffer for this function is significantly influenced by site-specific conditions such as soil type, subsoil permeability, and topography, including the morphology of the streambed and floodplain area, among other factors. Riparian areas with perfectly functioning conditions (PFC's) can reduce the effects of flood flows and desynchronize peak crests and flow rates of floods (Novitzki, 1979). Upland and wetland areas can infiltrate floodflows, which in turn, are released to the stream as baseflow. Vegetation in the riparian zone slows floodwaters, allowing infiltration, and alleviates downstream flooding (Bolton & Shellberg, 2001).

Riparian buffer widths for wildlife habitat vary greatly depending on individual wildlife species, but are generally on the order of 100 to 600 feet. (Appendix B, Knutson and Naef, 1997). Studies have found that a buffer of 100 feet is necessary to maintain macro-invertebrate diversity (Gregory et al., 1980); buffers of 100 to 165 feet are required for most amphibian and reptile species (Rudolph and Dickson, 1989). Larger riparian buffers of 300 to 650 feet are needed to provide adequate migration corridors for certain species of wildlife (such as birds and mammals). Quality of the buffer can also be a significant factor in determining the quality of wildlife habitat. For example, buffer zones comprised of native vegetation with multi-canopy structure, snags, and down logs provide habitat for the greatest range of wildlife species (McMillan, 2000). Presence of sensitive resources, such as areas inhabited by fish or wildlife species of special concern, are areas where larger buffers may be appropriate. Such an approach may minimize impacts to such species from impacts such as human intrusion, light and glare, and noise.

3.2 Stream Management in Urban Environments

Many recent studies have focused on the general effects of urbanization on streams in the lowland Puget Sound region (Booth, 2000; Horner and May, 1999). In these studies, a general trend has emerged that places a greater emphasis on evaluation of buffer effectiveness in the context of other watershed processes and evaluation of landscape-level alterations to watersheds (Roni et al., 2002; Richards et al., 1996).

The loss or disturbance of native riparian area is closely tied to urbanization in a watershed (Horner and May, 1999; Leavitt, 1998). However, water quality and coverage of impervious area have also been associated with stream degradation and impacts to native riparian areas. The adverse impacts of impervious area and water quality functions are compounded by degradation of riparian areas (Bledsoe and Watson, 2001; May et al., 1997). Effectiveness of a riparian area is limited where streams have been channelized or drainage routed through stormwater detention and treatment systems. Degraded riparian areas are less effective at removing sediments and pollutants washed from parking lots and roads where stormwater is not able to interact with streamside vegetation.

Land uses, such as high-density residential development or commercial development, located adjacent to riparian areas can result in greater impacts than lower density single-family residential uses (Pitt et al., 1986). Impacts may differ due to factors such as disturbance from light, noise, human intrusion, and edge effects on wildlife. Riparian areas, if intact, can separate streams from uplands and surrounding development, protecting streams from human encroachment, which can result in direct impacts to stream banks or channels, as well as aquatic life from increased access by humans or pets, and increased light or noise (Leavitt, 1998).

In most urban areas prescriptive buffers may not be adequate to restore streams because most of the functions of buffers have been compromised by past land use actions. For example, restoration of the natural woody debris recruitment function of riparian areas is difficult in areas that lack mature forested streamside vegetation (Larson, 2000). New watershed-based strategies may need to be implemented that would address hydrology, water quality, and riparian functions to successfully address management of buffer width and quality, land use controls, and stormwater management (Booth, 2000; Horner and May, 1999). When applied in the context of a basin-wide change, these strategies may most effectively address protection, enhancement, and restoration of stream systems.

3.3 Fisheries Habitat and Salmonid Use in the City of Tukwila

The City of Tukwila includes one river and four tributary watercourses that have documented salmonid use, and provide salmonid habitat (Adolfson, 1999). These include the Black River, Gilliam Creek, Southgate Creek, and Riverton Creek. Other small watercourses are located in the City, but are not known to provide opportunities for fish use due to significant habitat modification and isolation (Adolfson, 1999).

The Washington Administrative Code (WAC) states that special consideration must be given to "measures necessary to preserve or enhance anadromous fisheries." Consideration for "Anadromous" fish species refers to those species that reproduce in fresh water and migrate to salt water for some portion of their life, returning to fresh water. Some anadromous fish species repeat the cycle while others die after one cycle. The term "fisheries" commonly refers to stocks of fish that are managed for commercial, recreational, cultural, or ceremonial uses (WDFW, 1997).

The use of stream habitats varies by species, by developmental phase, or even by individuals within the larger population (Reiser and Bjornn, 1979). There are, however, many needs that are common to all anadromous fish, as well as to the overall health of many other aquatic organisms including benthic macroinvertebrates, which are an important food source for salmonids and other animals. These elements includes clean and cold water, suitably-sized spawning gravels and other in-stream diversity for use as habitat, food sources, rearing habitats in proximity to food, refuges from predators and environmental conditions such as sufficiently high flows, and unconstrained migration routes.

In urban settings where individual functions and elements of stream habitat are not optimal for salmonids, the combined effect of conditions in a stream basin may allow salmonids to successfully use its habitats (Appendix A). The combined effects of the individual processes that form and support habitat, such as input of organic material and substrate types, are sufficient to allow some salmonids to live and reproduce. In addition, small changes in stream function (e.g., improving habitat access by removing a fish-passage barrier), in combination with watershed-based restoration strategies, may provide substantial benefits to salmonid populations in urbanized basins.

The geographic location, topography, geology, and level of existing urbanization in the City of Tukwila limit the extent to which its streams can provide the necessary biological requirements for salmonid species and other aquatic organisms. The species potentially present in Tukwila waterbodies includes all Pacific salmon (except pink salmon), bull trout/Dolly Varden, coastal resident/sea-run cutthroat trout, rainbow trout/steelhead, and long-fin smelt (WDFW, 1998 and 1994; Wydoski and Whitney, 1979).

3.3.1 Green/Duwamish River

The Green/Duwamish River flows generally north through the City of Tukwila from approximately River Mile (RM) 5 to RM 17. The Green River flows north to become the Duwamish River in the vicinity of the confluence of the Black River. The Green/Duwamish River watershed is often referred to as Water Resources Inventory Area 9 (WRIA 9) (Kerwin, 2001). Both natural and man-made modifications during the early 1900's reduced the drainage basin to its present configuration, which is one quarter of its original extent (Warner and Fritz 1995). Presently, the Green/Duwamish River is completely constrained by dikes, limiting the river to its present channel.

The extensive water regime and channel modifications have resulted in existing habitat conditions that were not historically present in the Green/Duwamish River system. Most of the oxbows, side channels, sloughs, and associated wetlands historically present in the City have been filled or otherwise isolated from the river channel. Modification of the channel has changed the natural mixing action of the estuary, resulting in a distinct salt wedge and simplified mixing zone (Dawson and Tilley 1972 in Warner and Fritz 1995). Despite these changes, the Green/Duwamish River serves as an important salmonid transportation and rearing area (Williams *et al.*, 1975). Williams states that the lower Green/Duwamish River is "vital to salmon as a transition area for adaptation of migrants to salinity changes."

A fisheries investigation by Warner and Fritz (1995) identified 33 species of fish in the lower Green/Duwamish River system. Anadromous salmonid species such as Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), cutthroat trout (*Salmo clarki*), and bull trout (*Salvelinus confluentus*) were found in the lower river within City of Tukwila boundaries. Other salmonid species including chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead trout (*O. mykiss*), and other anadromous fish species such as lamprey (*Lampetra sp.*), smelt (*Spirinchus thaleichthys*), sticklebacks (*Gasterosteus aculeatus*), and mountain whitefish (*Prosopium williamsoni*) were also found in the lower Green/Duwamish River (Warner and Fritz, 1995).

3.3.2 Black River

The Black River is a remnant of the outlet of Lake Washington prior to the opening of the Montlake Cut and the Hiram Chittenden Locks in1916. At that time, the outlet was diverted from the Black River at the south end of Lake Washington to the Montlake Cut. The Black River now serves primarily as a stormwater detention basin and its flow is controlled by a flood control dam operated by the Corps of Engineers upstream of the City limits. Although only the mouth of the Black River is within the City, the river provides unobstructed off-channel rearing habitat and access to other watercourses beyond the City limits. Fish presence has been documented in the Black River (Kerwin, 2001).

3.3.3 Gilliam Creek

Gilliam Creek is the largest of the watercourses within the City, draining an area of approximately 1,800 acres between South 144th Street, Pacific Highway South, Strander Boulevard, and the Green/Duwamish River. Virtually the entire drainage basin has been developed, and the stream system has been fragmented throughout its entire length by long culverts, road crossings, development within buffer areas, channelization, and bank armoring.

Anadromous salmonid presence in Gilliam Creek is limited by a hanging culvert, with a 108-inch-diameter flap gate, passes under the dike of the Green/Duwamish River. Resident fish may be present in Gilliam Creek. However, this culvert largely precludes upstream fish passage except potentially during extremely high tides and/or high instream flow levels in the Green/Duwamish River. While Gilliam Creek does not likely contain suitable substrate or other habitats for use by spawning salmonids, approximately the lower 1,500 feet may provide foraging and rearing habitat. Anadromous salmonids have been observed in the lower section of Gilliam Creek (Adolfson, 1999).

3.3.4 Southgate Creek

The Southgate Creek basin is roughly delineated by 35th Avenue South, South 144th Street, Interstate 5, and the Green/Duwamish River. The area has been entirely developed, and like Gilliam Creek, Southgate Creek is fragmented throughout its length by long culverts, road crossings, buffer development, and channelization.

Southgate Creek is known to be used by juvenile coho and cutthroat trout (Adolfson, 1999). Anadromous salmonid species appear to have access to Southgate Creek from the Green/Duwamish River to Southgate Creek through a 72-inch culvert (with no flap gate). The lower 1,000 feet of the stream is known support fish rearing and foraging. However, spawning habitat is limited (Adolfson, 1999). Access to the upper areas of the drainage is precluded by several long culverts (Adolfson, 1999).

3.3.5 Riverton Creek

Riverton Creek drains an area approximately delineated by Military Road/33rd Avenue South, South 133rd Street, East Marginal Way, and the Green/Duwamish River. Virtually the entire drainage basin has been developed; and many long culverts, road crossings, urban development, and channelization have fragmented the stream habitat.

Riverton Creek flows into the Green/Duwamish River through a 60-inch culvert and a 48-inch culvert, both with flap gates. The lower portion of Riverton Creek creates a "moat" around an office complex that appears to be part of a remnant oxbow or side channel of the Green/Duwamish River. Upstream, Riverton Creek is generally confined to a narrow, straight engineered stream channel. Fish presence is documented up to large set of concrete steps in the channel, which blocks fish access upstream of Pacific Highway South (Adolfson, 1999). The lower portions of Riverton Creek are used by coho and cutthroat trout for foraging and rearing, but it is not known to contain suitable substrate or other habitats for spawning (Adolfson, 1999).

3.3.6 Other Watercourses

The City contains many small watercourses that are remnant portions of previously existing natural drainage systems, but are not known to support fish use (Adolfson, 1999). One such watercourse has limited open channel area and enters a pressurized drainage conveyance system west of Southcenter before discharging into the Green/Duwamish River near South 180th Street.

4.0 FUNCTIONS AND VALUES OF WATERCOURSES AND RIPARIAN AREAS IN TUKWILA

The City of Tukwila is in the process of updating their stream inventory. In this inventory, watercourses will be mapped and evaluated as to their ability to perform basic stream functions such as contributing to stream baseflow, water quality improvement, and providing in-stream habitat and structure.

Watercourses in Tukwila are primarily groundwater discharge systems. Groundwater emerges at the bottom of hillsides and on slopes as seeps, and either form watercourses or riparian wetlands. Riverton Creek, Southgate Creek, and Gilliam Creek are all examples of groundwater discharge systems. Precipitation and stormwater runoff are minor contributors to stream baseflow in Tukwila.

Water quality in the City's watercourses is largely un-documented. However, there is extensive scientific information available for the Green/Duwamish River. In general, temperature ranges for Tukwila watercourses are likely to fall within the upper levels of acceptable limits for healthy salmonid populations (Kerwin, 2001, Adolfson, 1999). As with many urban stream systems, the likely contributors to increased stream temperatures in Tukwila are lack of shade, low baseflows, degraded channels (high width-to-depth ratios), and warm water inputs from stormwater. Water temperatures likely exert some influence on dissolved oxygen levels in the City's streams, meaning that factors affecting stream temperatures also could influence dissolved oxygen levels. The steeper sections of streams in the City are likely to have high dissolved oxygen levels, while the slower and shallow gradient sections of streams are likely to have low dissolved oxygen levels that may not be healthy for fish. The Green/Duwamish River has been listed on the state 303(d) list of impaired waters for temperature and dissolved oxygen levels (Kerwin, 2001). As for pollutants and metals, little specific information is known about the presence of toxic substances in Tukwila's watercourses. However, the Green/Duwamish River is listed on Washington state's 303(d) list for mercury, metals, pH, and fecal coliform (Kerwin, 2001).

In-stream habitat structure includes substrate, LWD, pool quality and frequency, and refugia. All species of salmonids present in Tukwila streams require clean gravel to spawn, and under natural conditions, bank erosion and channel movement replenish stream gravel, providing new gravel for spawning. There has been limited documentation of substrate types in Tukwila's watercourses. However, given the extent of impervious cover in the City's basins and the likely associated high flows, it is probable that native substrate has been altered by erosion and sedimentation (Kerwin, 2001). Off-channel wetlands and side channels are rare in the City of Tukwila, as most of the wetlands are disconnected from streams, and many of the stream channels have been modified and straightened.

There is little documentation related to specific pool quality or habitat frequency in Tukwila's streams. Studies have shown, however, that stream habitat in urban and urbanizing streams typically includes reduced pool frequency and reduced overall habitat quality (May, et al., 1997). As one example, May, et al. (1997) found a dramatic decline in habitat functions as total basin impervious area increased above the 5 to 10 percent range. Two significant factors limiting stream habitat structure in urban areas include the lack of pool-forming large woody debris recruitment from riparian areas and increased frequency and magnitude of peak discharge rates, which may scour pools and woody debris from the channel.

Riparian stream buffers in the City of Tukwila are varied in width and condition depending on location in the watershed. Typically, the headwater and upper portions of streams in Tukwila have intact, forested buffers. However, in the lower sections of the streams, urbanization has encroached on the riparian zone, and the ability of buffers to perform functions such as large woody debris recruitment or water quality improvement have been compromised.

5.0 DATA GAPS

Two data gaps were discovered in the preparation of this study. The first is the lack of best available science literature pertaining to urbanizing watersheds and buffers needed to protect environmentally sensitive areas in the urban areas of the Pacific Northwest.

The second data gap is the lack of detailed and specific information on each of Tukwila's watercourses and riparian habitat. In addition to the watercourse inventory currently being prepared by the City, an assessment of fish and wildlife use in Tukwila's streams and riparian corridors would prove useful in making policy decisions and modifications regarding sensitive areas. In addition, documentation of water quality parameters and buffer quality could be included as part of this background documentation.

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APPENDIX A: EFFECTS OF ECOSYSTEM ALTERATIONS ON SALMONIDS

Ecosystem Feature	Altered Component	Effects on Salmonid Fishes and Their Ecosystems
Water Quality	Increased Temperature	Altered adult migration patterns, accelerated development of eggs and alevins, earlier fry emergence, increased metabolism, behavioral avoidance at high temperatures, increased primary and secondary production, increased susceptibility of both juveniles and adults to certain parasites and diseases, altered competitive interactions between species, mortality at sustained temperatures of >73-84□ F, reduced biodiversity.
	Decreased Temperature	Cessation of spawning, increased egg mortalities, susceptibility to disease.
	Dissolved Oxygen	Reduced survival of eggs and alevins, smaller size at emergence, increased physiological stress, reduced growth.
	Gas Supersaturation	Increased mortality of migrating salmon.
	Nutrient Loading	Increased primary and secondary production, possible oxygen depletion during extreme algal blooms, lower survival and productivity, increased eutrophication rate of standing waters, certain nutrients (e.g., nonionized ammonia, some metals) possibly toxic to eggs and juveniles at high concentrations.
Sediment/Substrate	Surface Erosion	Reduced survival of eggs and alevins, reduced primary and secondary productivity, interference with feedings, behavioral avoidance and breakdown of social organization, pool filling.
	Mass Failures and Landslides	Reduced survival of eggs and alevins, reduced primary and secondary productivity, behavioral avoidance, formation of upstream migration barriers, pool filling, addition of new large structure to channels.
Habitat Access	Physical Barriers	Loss of spawning habitat for adults; inability of juveniles to reach overwintering sites or thermal refugia, loss of summer rearing habitat, increased vulnerability to predation.
Channel Structure	Flood Plains	Loss of overwintering habitat, loss of refuge from high flows, loss of inputs of organic matter and large wood, loss of sediment removal capacity.
Channel Structure (contd.)	Side-Channels	Loss of overwintering habitat, loss of refuge from high flows.
	Pools and Riffles	Shift in the balance of species, loss of deep water cover and adult holding areas, reduced rearing sites for yearling and older juveniles.
	Large Wood	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates, formation of new migration barriers, reduced capacity to trap salmon carcasses.

Ecosystem Feature	Altered Component	Effects on Salmonid Fishes and Their Ecosystems
	Substrate	Reduced survival of eggs and alevins, loss of inter-gravel spaces used for refuge by fry, reduced macroinvertebrate production, reduced biodiversity.
	Hyporheic Zone (biologically active groundwater area)	Reduced exchange of nutrients between surface and subsurface waters and between aquatic and terrestrial ecosystems, reduced potential for recolonizing disturbed substrates.
Hydrology	Discharge	Altered timing of discharge related life cycle cue (e.g., migrations), changes in availability of food organisms related to timing of emergence and recovery after disturbance, altered transport of sediment and fine particulate organic matter, reduced prey diversity.
	Peak Flows	Scour-related mortality of eggs and alevins, reduced primary and secondary productivity, long-term depletion of large wood and organic matter, involuntary downstream movement of juveniles during high water flows, accelerated erosion of streambanks.
	Low Flows	Crowding and increased competition for foraging sites, reduced primary and secondary productivity, increased vulnerability to predation, increased fine sediment deposition.
	Rapid Fluctuations	Altered timing of discharge-related life cycle events (e.g., migrations), stranding, redd dewatering, intermittent connections between mainstream and floodplain rearing habitats, reduced primary and secondary productivity.
Riparian Forest	Production of Large Wood	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates.
	Production of Food Organisms and Organic Matter	Reduced production and abundance of certain macroinvertebrates, reduced surface-drifting food items, reduced growth in some seasons.
	Shading	Increased water temperature, increased primary and secondary production, reduced overhead cover, altered foraging efficiency.
	Vegetative Rooting Systems and Streambank Integrity	Loss of cover along channel margins, decreased channel stability, increased streambank erosion, increased landslides.
	Nutrient Modification	Altered nutrient inputs from terrestrial ecosystems, altered primary and secondary production.
Exogenous Material	Chemicals	Reduced survival of eggs and alevins, toxicity to juveniles and adults, increased physiological stress, altered primary and secondary production, reduced biodiversity.
	Exotic Organisms/Plants	Increased mortality through predation, increased interspecific competition, introduction of diseases, habitat structure alteration.

Source: http://www.psmfc.org/efh/Jan99-sec3-2.htm

APPENDIX B: LITERATURE FINDINGS, RIPARIAN BUFFERS BY FUNCTION

Buffer Functions	Riparian Buffer Width Studied (feet)	Reference	Notes
Sediment Removal	100	Castelle & Johnson, 2000	Approaches 100% particulate organic matter production
	100	Lynch et al., 1985	75-80% removal
	100	Wong & McCuen, 1982	90% removal
	200	Wong & McCuen, 1982	95% removal
	200	Horner & Mar, 1982	80% removal in grassy swale
	200	Broderson, 1973	Removal of most sediment on slopes > 50%
	290	Gilliam & Skaggs, 1986	50% deposition
	295 - 400	Wilson, 1967	Clay
Pollutant Removal	13	Doyle et al., 1975	Grass buffers
	15	Madison et al., 1992	90% removal of NH4-N, NO3-N, and PO4-P
	50	Castelle et al., 1992	80% pollutant removal
	53	Jacobs & Gilliam, 1985	Most sediment removal
	100	Lynch et al., 1985	75-80% pollutant removal
	100	Grismer, 1981	Reduced fecal coliforms by 60%
	120	Young et al., 1980	Minimum for nutrient reduction
	300	Vanderholm & Dickey, 1978	80% removal on a 0.5% slope
	860	Vanderholm & Dickey, 1978	80% removal on a 4% slope
Large Woody Debris Recruitment	16 - 33	Castelle & Johnson, 2000	40-60% LOD input
	33	McDade et al., 1990	<50% of naturally occurring LOD
	50	McDade et al., 1990	60-90% of all LOD
	65 - 100	Castelle & Johnson, 2000	80-100% LOD input
	65	Murphy & Koski, 1989	95% of LOD
	100	McDade et al., 1990	85% of nat. occurring LOD
	100	May et al., 1997	Recommended minimum
	150	Harmon et al., 1986	Supply most LOD
	150	Robison & Beschta, 1990	Supply most LOD
	165	Van Sickle & Gregory, 1990	Minimum for LOD input
	330	May et al., 1997	Sensitive streams
Stream Water Temp. Moderation	35 - 80	Brazier & Brown, 1973	60-80% shade
	40	Corbett & Lynch, 1985	Control stream temperature fluctuations

Buffer Functions	Riparian Buffer Width Studied (feet)	Reference	Notes
	50	Broderson, 1973	Buffer widths decrease as tree heights increase
	55	Steinblums et al., 1984	Maximum angular canopy density
	55	Moring, 1975	Maintain stream temperature if forested conditions
	75 - 90	Steinblums et al., 1984	60-80% shade
	100	Beschta et al., 1987	Minimum shade to level of old growth forest
	100	Lynch et al., 1985	Maintain stream temperatures that are within 1C of areas that are fully forested
Maintenance of Benthic Communities	33	Culp and Davies, 1983	Minimum for healthy communities
	100	Roby et al., 1977	Maintain benthic communities similar to streams in fully forested areas
	100	Newbold et al., 1980	Maintain healthy benthic communities
	100	Castelle & Johnson, 2000	Minimum for healthy benthic communities
	100	Erman et al., 1977	Maintain macroinvert diversity
	>100	May et al., 1997	Benthic integrity or B-IBI - high in stream with >70% upstream buffer intact
	>100	Erman et al., 1977	Macroinverts similar to prelogged condition
Wildlife Habitat	100	Gregory et al., 1980	Macroinvertebrate diversity
	100-300	Castelle et al., 1992	Range for most wildlife species
	100 - 310	Rudolph & Dickson, 1990	Reptiles & amphibians
	105	Groffman et al., 1990	Forested buffer for minimizing noise impacts to wildlife

(Adolfson, 2002)